



Original communication

Forensic and clinical carbon monoxide (CO) poisonings in Turkey:
A detailed analysis

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ABSTRACT

Carbon monoxide (CO) is produced by incomplete combustion of organic compounds. Its intoxication usually results from inhalation of fumes from improper heating stoves, motor vehicles, or smoke from fires. It can reversibly bind various heme-containing proteins such as hemoglobin, myoglobin, cytochrome p450 and cytochrome oxidases. Among them, it has a high affinity for hemoglobin (230–270 times more avidly than oxygen) with which it forms carboxy-hemoglobin (HbCO) leading to decrease in oxygen-carrying capacity followed by end-organ hypoxia. A tissue hypoxia may then result in transient or permanent damage of important organs like central nervous system and even death. CO poisonings from different reasons are an important cause of morbidity and mortality in Turkey. The purpose of this study on CO poisonings in Turkey is to sum up and analyze the best available researches in both forensic and clinical toxicology fields. This was achieved by synthesizing the results of Turkish and English papers on forensic and clinical CO poisoning cases conducted in universities, institutes, hospitals and other official or private organizations in Turkey. Total of 47,523 medico-legal autopsy data collected from 9 different forensic medicine branches and emergency rooms in different year intervals were reviewed and 980 CO poisoning cases were determined. To calculate the frequency of CO poisoning within all the autopsies carried out and fatal poisoning cases, the number of cases was divided by the total number of medico-legal autopsies and total fatal poisoning cases. The mean age of cases, the source of CO gas, the most common seasons and months, gender, and blood HbCO levels were also taken into consideration if the data is available. Under the light of the findings, we may suggest that determination of affecting factors in CO poisoning is going to be one of the key subjects for planning preventive interventions.

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1. Introduction

Carbon monoxide (CO) is a colorless, odorless, tasteless, and nonirritating toxic gas that is produced by incomplete combustion of organic compounds. Although everyone has CO in their blood about less than 5% (the saturation concentration), heavy smokers and those in certain occupations may reach 10% saturation. Healthy

individuals can survive with blood saturations of 40% for a minute or of 20% for a week. Those fatally exposed to the fumes of an internal combustion engine usually have blood concentration of CO 60% or more.¹ Improperly installed heaters, motor vehicles, appliances that use carbon fuels, and most importantly household fires are the main sources for CO gas. The heating units of residential, occupational or institutional places are poorly maintained or not well maintained. In such places, retrograde flow in the system can occur in the presence of pressure problems, chimney or equipment malfunctions. In poorly ventilated places, the usage of improper heating systems may lead to deaths within a short time interval or CO poisoning with immediate death may occur during fires.² According to the Centers for Disease Control and Prevention

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Table 1
The medico-legal autopsies, fatal poisonings, and carbon monoxide poisonings in several Turkish cities according to their year intervals and authors who conducted the retrospective study.

No.	Author	Province	(a) Total # of autopsies	(b) Total # of fatal poisonings	(c) Total # of CO poisonings	$b/a \times 100$ (%)	$c/b \times 100$ (%)	$c/a \times 100$ (%)	Year interval	Total year	Mean age of victims
1	Birincioglu et al. ⁹	Trabzon	4492	285	180	6.34	63.0	4.00	1998–2008	11	21.6
2	Buyuk et al. ¹⁰	Istanbul	15,418	320	104	2.07	32.5	0.70	1998–2003	6	36.6
3	Azmak et al. ¹¹	Edirne	1206	134	11	11.11	8.2	0.90	1984–2004	21	41.9
4	Canturk et al. ¹²	Ankara	4539	n.a.	175	n.a.	n.a.	3.85	2002–2006	5	n.a.
5	Erturk et al. ¹³	Izmir	2740	253	67	9.20	26.5	2.44	1990–1994	5	n.a.
6	Duman et al. ¹⁴	Izmir	4251	331	89	7.80	27.0	2.10	1996–2000	5	n.a.
7	Goren et al. ¹⁸	Diyarbakir	5891	52	11	0.90	15.4	0.20	1994–2003	10	28.8
8	Turkmen N et al. ¹⁹	Bursa	3,065	n.a.	99	n.a.	n.a.	3.23	1999–2003	5	n.a.
9 ^a	Karapirli et al.	Ankara	5921	366	244	6.17	66.7	4.12	2007–2011	5	45.9
Total	—	9	47,523	—	980	—	—	—	—	—	—

n.a.: Not available.

^a Unpublished data.

(CDCP), CO poisoning is the reason for 50,000 visits to the emergency departments in the United States and contributes to approximately 2700 deaths annually.³

CO poisoning is one of the most important causes of morbidity and mortality in Turkey especially in winter season. Likewise, CO intoxication takes place among the leading causes of deaths due to poisonings in Turkey.⁴ It is also the most common cause of death in combustion-related inhalation injuries. Although unintended poisoning with CO shows seasonal and regional variations in the world, it is the most common type of poisoning during winter months in cold climate areas of Turkey. In this study, we aimed to reveal the most recent status of CO poisonings in both forensic and clinical toxicology aspects with current statistical data.

2. Materials and methods

This is a retrospective study dealing with the whole scientific reports of CO poisoning related deaths in Turkey in terms of forensic and clinical cases between 1984 and 2011 (27 years). All the written reports in both Turkish and English language are included in the scope of the study so that the readers can see the present and past situation regarding CO poisonings from different cities of Turkey as a glance. The distribution of cases among provinces, yearly distribution of CO poisoning cases, seasonal and monthly dispersions have also been transferred to this article from previously conducted ones. The cases were collected from the manuscripts focused on a total of 7 cities and 47,523 legal autopsies performed by Forensic Medicine departments. Clinical CO poisoning cases from 4 cities and the reports dealing with whole Turkish cities were examined per se.

The CO poisoning cases in terms of percentage were calculated by using (a) total number of autopsies stated in each study, (b) total number of fatal poisonings, and (c) total number of CO poisonings (the values were calculated from multiplying the numbers with 100 after divisions procedures as b/a , c/b , and c/a). The year intervals, the mean ages of victims, genders, the sources of CO gas, the most common season for CO poisonings, the most common month for CO poisoning, and blood HbCO levels, wherever possible, were collected in same tables. In addition to individual data from different studies, the distribution of total CO poisoning cases in Turkey and the time intervals in terms of numbers and the percentages within the medico-legal autopsies were also summarized in the tables.

3. Results

The results are summarized in Tables 1–6 and Figs. 1 and 2. Figures show the cities on the map in which CO poisoning cases occurred. Table 1 shows the medico-legal autopsies, fatal poisonings, and CO poisoning cases in several Turkish cities according to their years and authors who conducted the study. A total of 980 CO poisoning cases were extracted from 47,523 total autopsies performed by several Forensic Medicine departments centered in 7 cities. The years that were investigated in terms of CO poisonings were between 1984 and 2011. The most long-term study was performed by Azmak et al. with a total of 21 years. The characteristics of the victims of CO poisoning are summarized in Table 2. The highest and lowest mean ages were detected from the studies held in Ankara and Istanbul. The most common month for CO poisoning was January. Males were much more affected from

Table 2
The characteristics of the victims of carbon monoxide poisonings in Turkey.

No.	Author	Province	Mean age of victims (years)	The source of CO			The most common season of CO poisoning (%)	The most common month of CO poisoning	Gender		HbCO levels in blood (% saturation)
				Coal stove (%)	Water heater (%)	Fire (%)			M (%)	F (%)	
1	Birincioglu et al. ⁹	Trabzon	37.2	33.3	33.8	20.5	Winter	January	n.a.	n.a.	n.a.
2	Buyuk et al. ¹⁰	Istanbul	36.6	n.a.	n.a.	100	Winter (40.9%)	n.a.	71.3	28.7	0–upper 50
3	Azmak et al. ¹¹	Edirne	n.a.	n.a.	99.0	n.a.	Winter (98.5%)	n.a.	54.5	45.5	49–61
4	Canturk et al. ¹²	Ankara	40.3	61.1	24.0	6.3	Winter (43.3%)	December	62.9	37.1	22.6–80.2
5	Erturk et al. ¹³	Izmir	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	Duman et al. ¹⁴	Izmir	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	Goren et al. ¹⁸	Diyarbakir	n.a.	n.a.	100	n.a.	Winter	n.a.	67.7	32.3	n.a.
8	Turkmen et al. ¹⁹	Bursa	37.7	48.5	28.3	n.a.	Winter	January and December	61.6	38.4	22–50
9 ^a	Karapirli et al.	Ankara	48.8	n.a.	n.a.	n.a.	Winter (55.3%)	January	55.3	44.7	57.0

n.a.: Not available.

^a Unpublished data.

Table 3

The characteristics of patients who admitted to emergency rooms of hospitals for CO poisoning.

No.	Author	Province	(a) Total # of admission	(b) Total # of poisonings	(c) Total # of CO poisonings	Total # of death	c/a × 100 (%)	c/b × 100 (%)	The rate of the death	Year interval	Total years	Mean age	HbCO (% saturation)
1 ^a	Metin et al. ¹⁷	Turkey	10,154	10,154	10,154	39	n.a.	n.a.	0.4	n.a.	n.a.	n.a.	n.a.
2	Andiran et al. ³¹	Ankara	489	n.a.	46	n.a.	9.4	n.a.	n.a.	1995–2000	6	5.96 ± 4.87	n.a.
3	Keles et al. ³²	Ankara	n.a.	n.a.	323	n.a.	n.a.	n.a.	n.a.	2002–2003	2	n.a.	26.3 ± 11.5
4	Akkose et al. ¹⁶	Bursa	n.a.	n.a.	305	10	n.a.	n.a.	3.3	1996–2006	11	36.8 ± 16.2	21.6 ± 0.9
5	Demircan et al. ³⁵	Ankara	13,823	n.a.	915	n.a.	6.6	n.a.	n.a.	2000–2005	6	28.0 ± 16.4	n.a.
6	Uyanikoglu et al. ³⁶	Istanbul	n.a.	794	83	n.a.	n.a.	10.4	n.a.	2005–2005	1	n.a.	n.a.
7	Kekec et al. ³⁷	Kayseri	n.a.	682	93	2	n.a.	13.7	2.0	n.a.	n.a.	n.a.	n.a.

n.a.: Not available.

^a Review article.

CO poisonings than females (the most remarkable result was from Izmir, the percentage was 71.3% vs. 28.7%). The characteristics of patients who were admitted to the emergency departments for CO poisoning can be seen in Table 3. Total number of hospital admissions due to CO poisoning was 24,466, the data was mostly from Ankara. The rate of death was found to be 0.4% for whole Turkey, 3.3% for Bursa, and 2% for Kayseri (note that there are limited results for the calculation of rate of death). Table 4 has collective data showing the city statistics. The repeated studies in the same city with different time intervals were gathered as one result in this table. Also, the study conducted in Diyarbakir and Istanbul was not included in the table because they cannot show the same data as the others. Because the bathroom deaths were investigated in Diyarbakir and the asphyxial deaths were investigated in Istanbul. These studies were designed to see the CO poisoning cases within only a certain population rather than all population. The percentage of CO poisoning cases compared to total autopsies performed was 4% in Ankara, 2.2% in Izmir, 4% in Trabzon, 3.2% in Bursa, and 0.9% in Edirne. Total medico-legal autopsies and the number and percentages of CO poisoning cases according to their year intervals were presented in Table 5. The highest number of CO poisoning cases was encountered between 2006 and 2011 (4.7%). The lowest one was between 1996 and 2000 (2.3%). The gender of victims, the seasons when most cases occurred, and the manner of deaths in total CO poisoning cases are summarized in Table 6. We collected these data from only limited studies that can give available information for gender, season, and manners of death. The percentages of male and female were 65.3% and 34.7%, respectively. Winter was the most common season for CO poisoning. The majority of the cases (calculated from only available data) were unintentional poisonings, but not suicide.

Table 4

Total medico-legal autopsies and the number and percentage of carbon monoxide poisoning cases according to cities.

	CO poisoning cases		All the cases except CO poisonings		Total autopsies	
	n	%	n	%	n	%
Ankara	419	4.0	10,041	96.0	10,460	100.0
Izmir	156	2.2	6835	97.8	6991	100.0
Trabzon	180	4.0	4312	96.0	4492	100.0
Bursa	99	3.2	2966	96.8	3065	100.0
Edirne	11	0.9	1195	99.1	1206	100.0

4. Discussion

4.1. Forensic carbon monoxide poisoning data in Turkey

There is a lack of documentation of CO poisonings in Turkey. Tables 1 and 2 summarize and review all the CO poisoning cases on medico-legal autopsies by related branches of Council of Forensic Medicine of Turkey. Fatal poisoning due to CO is a common problem in Turkey while alcohol and drug related deaths are known as a major problem in Western societies in comparison to the other societies.^{5–8} Only a few manuscripts dealing with the fatal poisonings in Turkey were found. Also, a few papers focusing on the CO poisoning were found and reviewed in detail.

To contribute additional data to the literature on the subject, the characteristics of medico-legal autopsies of fatal poisonings in Trabzon (Turkey) from 1998 to 2008 were investigated by authors.⁹ HbCO saturation was measured by a spectrophotometric method while the other toxicological analyses were measured by available instrumental methods. A total of 4492 autopsies were performed and 285 of them were assigned to be fatal poisonings with different causes. Among them, CO poisoning was the most common cause of death ($n = 180$, 63%). CO poisonings were gradually increased by years starting with 1998 up to 2008. Mean age of the victims was 37.16 ± 22.65 years. The most common season in which CO poisoning occurred was winter and January was the most common month. They showed the source of CO as water heaters in the bath (33.8%), coal stoves (33.3%) and fires (20.5%), while the remaining 12.4% was a result of other causes like exhaust gases. They classified the CO poisoning as a result of unintentional exposure. The other observation was the highest CO poisoning in 2007: unusual and abnormal snowfall at that year with strong northwesterly winds led people to use improper coal stoves. The use of gas boilers set up

Table 5

Total medico-legal autopsies and the number and percentage of carbon monoxide poisoning cases according to their year intervals.

	CO poisoning cases		All the cases except CO poisonings		Total autopsies	
	n	%	n	%	n	%
1990–1995	67	2.5	2673	97.5	2740	100.0
1996–2000	120	2.3	5154	97.7	5274	100.0
2001–2005	198	3.6	5296	96.4	5494	100.0
2006–2011	289	4.7	5921	95.3	6210	100.0

Table 6
The gender of the victims, the seasons when most cases occurred, and the manner of deaths in total CO poisoning cases in Turkey.

	n	%
Gender (n = 352) ^{11–13,19}		
Male	230	65.3
Female	122	34.7
Season (n = 474) ^{9,11,12,19}		
Winter	210	44.3
Spring	137	28.9
Summer	34	7.2
Autumn	93	19.6
Manners of death (n = 248) ^{11–13}		
Accident	244	98.4
Suicide	4	1.6

in the bathrooms is the other reason. Even if the percentage of CO poisoning is pretty high, the authors estimate that most of the poisoning was preventable by the help of community education and utilization of CO detector in risky places. In summary, authors suggested that CO poisoning was a serious risk factor for mortality in city of Trabzon and the surrounding provinces.

Buyuk et al.¹⁰ studied fire-related deaths whose autopsies were carried out in the Council of Forensic Medicine in Istanbul, Turkey. They documented the postmortem findings of fire-related fatalities and evaluated the relationship among the mode of death and autopsy and laboratory findings which form the basis of assessment of these cases in forensic autopsies. Total of 15,418 autopsies performed between 1998 and 2003 were reviewed retrospectively by the authors and 320 fire burn cases were evaluated. These cases constituted the 2.07% of all autopsies. According to the gender, 228 cases (71.3%) were males and 91 cases (28.4%) were females. The age of the cases ranged between 8 months and 98 years (36.6 ± 21.98 years). Most of the cases were encountered in winter season (40.9%) although the least number was in summer (14.7%). The main reason for death in 104 cases out of 320 was CO intoxication. The distribution of HbCO levels in the blood of victims was 0–10% in 72 cases, 11–50% in 123 cases, greater than 50% in 24 cases. There was no record for 101 people. They found the relationship between the level of CO in blood and the origin of fire to be significant. In case of accident, arson, or explosion, HbCO levels were found to be over 50%. HbCO level was found between 1% and 10% in 70% of the suicidal cases, on the other hand, between 11% and 50% in 30% of the suicidal cases. In the 12 accidental fire deaths, it was found that the victims were alive at the time fire started. The blood has no CO, therefore, the death was thought to be arising from carbon dioxide poisoning (CO₂) or relative oxygen deficiency.

Asphyxial deaths were investigated by Azmak in the Trakya region of Turkey (Edirne and nearby area) and compared them to the other worldwide studies.¹¹ Total 1206 autopsies including 852 medico-legal autopsies were investigated retrospectively and 134 cases were found to be asphyxia cases. Total 11 of the deaths (8.2%) was due to CO poisoning. The age range was 15–82 years. Ten of 11 deaths occurred in the winter months and 9 of the cases were found dead in the bathroom using a shower connected to the gas water heater or charcoal-heating devices. Blood HbCO saturations were found to be in the range of 49–61%.

Canturk et al.¹² investigated CO poisoning in Ankara between 2002 and 2006 for a 5-year period. Total of 4539 medico-legal autopsies were reviewed retrospectively and 175 of the deaths were found to be due to CO poisoning (3.85%). When the data analyzed according to the years, it was found that 27 of total 709 autopsies in 2002 (3.81%), 27 of total 806 autopsies in 2003 (3.35%), 30 of 896 autopsies (3.35%) in 2004, 46 of total 1039 autopsies in 2005 (4.43%), and 45 of total 1089 autopsies in 2006 (4.13%) were due to CO poisoning. The ages of victims ranged between 1 and 95 years with a mean age of 40.3 ± 21.8 years. Total of 62.9% of the cases were male and the mean HbCO level was 53.37 ± 14.45% saturation ranging between 22.6% and 80.2%. They gave the causes of CO poisoning as follows: 172 cases were attributed to unintentional reason (98.3%) and 3 cases were attributed to suicide (1.7%). Suicides took place in vehicles set up exhaust gas into the vehicle. The CO poisonings were attributed to coal stove for heating purpose (61.1%), water heater with shower system (24%), fire of house or building (6.3%), barbecue with a charcoal burner indoor space (3.4%), water heater for heating of the house (2.3%), exhaust gas of automobile (2.3%), and an explosion in coal mine area (0.9%). Total of 159 people died in their homes (90.8%), 7 people in vehicle (4%), 6 people in workplace (3.4%), and 3 people within a cave (1.7%). They also investigated the seasons in which CO poisonings took place: it was found that 76 cases died in winter season (43.3%), 44 cases in spring season (25.1%), 41 cases in autumn season (23.4%), and 14 cases in summer season (8.0%).

Medico-legal autopsies were performed for 2740 cases in Izmir Branch of Council of Forensic Medicine between 1990 and 1994. Of the total cases, 253 deaths were due to fatal poisoning like insecticides, alcohol, medicine, CO and others.¹³ Total 67 of deaths, 53 male and 14 female, was due to CO poisoning (27%). The most of the cases for CO poisonings were 20–29 years old followed by 10–19 years old and 30–39 years old. CO poisonings were attributed to either unintentional accidents (61 of the cases, 91%) and commit suicide (1 of the cases, 1.5%), despite 6 of the cases (9%) remained unidentified in terms of the reason of CO poisoning. The scene investigation findings of CO poisoning were residence (home)



Fig. 1. Representing the cities on the geographical map of Turkey in which the medico-legal autopsies were carried out by the branches of Council of Forensic Medicine and some emergency departments and the CO poisoning cases determined up to now.



Fig. 2. Representing the cities on the geographical map of Turkey in which the clinical CO poisonings were determined by the emergency rooms of hospitals.

($n = 34$, 51%), medical care units ($n = 11$, 16%), workplace ($n = 9$, 13%), and unidentified because of several reasons ($n = 13$, 20%).

Izmir Branch of Forensic Medicine carried out another study on 4251 medico-legal autopsies between 1996 and 2000 years. Among these autopsies, 331 fatal poisoning cases (206 men and 125 females) were evaluated under the light of legal investigation results, autopsy findings and toxicological analyses. Carbon monoxide poisoning was the second most common cause for death of the cases (28%).¹⁴

Tekbas et al.¹⁵ conducted a study upon two deaths to measure CO levels during the operation of hot water boilers that use liquefied petroleum gas or natural gas, which are widely used in Turkey. Carbon monoxide levels were measured in the bathrooms of homes in a housing area where the deaths took place on the same day. In 44 (22.4%) of the bathroom studied, CO levels were above 9 ppm which is the 8-h limit according to the NAAQS. CO levels in 2 bathrooms (0.7%) were found to be above 35 ppm, the maximum 1-h exposure level. CO levels above 50 ppm were determined in 6% of the houses. The investigators found that CO levels were higher than risk levels for intoxication in 20% of the houses.

According to the data of Bursa Branch of Council of Forensic Medicine, 211 people died because of CO poisoning due to unintentional reasons in home or workplaces.¹⁶

In a Turkish review article, authors investigated the frequency of CO poisoning in Turkey in 2010.¹⁷ They reached to valuable information revealing the most recent situation of CO poisoning of Turkey. The CO poisoning case records of Ministry of Health Treatment Services General Directorate in 2010 has been examined. The distribution of cases among regions-provinces, mortality rates, types of CO sources, seasonal and monthly dispersions were also examined in this article. Total 10,154 CO poisoning cases were detected and only 39 of them died. The frequency of cases was detected as 14 in every 100,000, and the mortality rate was calculated as 5 in every 10 million people. The highest number of deaths was seen in Marmara Region (33.7%). Bursa has the highest number of cases ending with death (18 cases) at that time period. On the other hand Kilis city was found to have the highest number of cases according to the population (about 0.2%).

Because bathroom deaths is one of the most common death types in Turkey arising from the heating system, reports of 5891 death examination and autopsies performed at Diyarbakir Branch of Forensic Medicine between 1994 and 2003 were reviewed and 52 bathroom deaths were evaluated.¹⁸ The percentage of males was 67.7% and the mean age of cases was 28.8 years with the range of 10 months–88 years. The most frequent deaths were found to be in 11–20 age groups. The nature of the deaths was either accident (69.2%) or suicide (30.8%). Of 52 deaths, 8 were attributed to CO poisoning (15.4% within all bathroom deaths).

Authors aimed to investigate different features of CO poisoning related deaths autopsied in Bursa in 5-year period (between 1999 and 2003) and demonstrated medico-legal aspects.¹⁹ At that time period, 3065 forensic autopsies and crime scene reports were evaluated, 99 deaths due to CO poisoning were documented retrospectively. It reveals a percentage of 3.2 within all forensic autopsies. Median age was 37.7 years and 61.6% of the cases were male. Winter was the most common season for CO poisoning and 79.8% of the deaths occurred at home followed by workplaces (7.1%) and hospitals (4.0%). The sources of CO were coal stoves (48.5%) followed by water heater with gas system in bathrooms (28.3%) and the others like exhaust, caves, etc. In 41 cases (41%), HbCO levels were between 31 and 40% followed by 22 cases (22%) with a HbCO level of 41–50%.

According to our unpublished data on fatal poisonings in Ankara Branch of Forensic Medicine between 2006 and 2011, within 5921 medico-legal autopsies, fatal poisonings were found to be 366 (6.17%) and of those cases, the number of CO poisonings was 244 (66.7%).

When we compare Turkey with other countries in terms of the deaths due to CO poisoning, we notice that the type of poisoning and the other parameters had totally different statistics. In Central China (Hubei), of the 212 poisoning deaths, 36 deaths were due to CO poisoning (17.0%).^{20, 21} The scene investigation findings of CO poisoning were residence (home) (51.4%), hotel (34.3%), and rented apartments (14.3%). At the same study, authors conclude that CO intoxication was the number one cause of accidental poisoning deaths. The majority of the accidents were caused by gas inhalation (51%). Another study analyzed the deaths by CO poisoning in Cuyahoga County, Ohio, USA, including its largest city, Cleveland for an 11-year period.²² The postmortem data showed that in the 11-year period, there were 209 accidental deaths (unintentional) due to fires and thereby CO in the home (6.5% of total deaths attributed to accidents in the home and 0.6% of the total deaths investigated) and 182 CO deaths by suicide (9.8% of total deaths attributed to suicide and 0.6% of the total deaths investigated). Fire deaths were prevalent in the young and old people whereas in the suicide group, the age specific death rate was highest for those over 70 years. A total of 128 males and 54 females committed suicide by using CO. The age distribution of intentional CO poisonings was as following: 7 suicides by CO poisoning among 10–19 years old, 41 suicides among 30–39 years old, 36 suicides among 40–49 years old, 15 suicides among 50–59 years old, 19 suicides among 60–69 years old, 27 suicides among 70–79 years old, and 11 suicides among those 80 years old and over. In the medico-legal 13,819 autopsies carried out by Institute of Forensic Medicine in Greifswald, Germany, CO-intoxications among the fatal poisonings were found most frequently with an incidence of 49% followed by alcohol

intoxications with 21%.²³ Naso et al.²⁴ conducted a study to provide supplementary information on postmortem toxicology in a pediatric population, defined as children up to 18 years old. Of 247 fatal poisonings, 20 cases (8%) were positive for CO. The highest number of deaths positive for CO occurred in the “greater than 2–12 years old group” (55%), followed by “greater than 1 day–2 years group” (25%). In 85% of cases, the ruling was accidental death and occurred due to fires in the home. There were also homicides (10%) and suicide (5%). The homicides were due to a house fire and the suicide was an intentional automobile collision. In 646 forensic autopsy cases, there were 53 child cases under the age of 15 years and 121 elderly cases 65 years old and above.²⁵ Of child deaths, 40% were described as accidental and 6 of them were attributed to house fire and 2 of them were attributed to CO due to deficient gas apparatus. Elderly deaths (60.3%) were accidental and fire deaths were the most frequent (32.2% of all cases) one. One of the largest studies on fatal poisoning in childhood was conducted by Flanagan et al. in England and Wales between 1968 and 2000.²⁶ Of total 2907 fatal poisoning in children under 10 years old, 1691 (58%) was due to CO intoxication and the reasons were accident ($n = 1,560$), homicide ($n = 109$), and open verdict ($n = 22$). Fatal poisonings from CO in this age group were attributed to accidental fire and flames (78.7%), accidental poisoning (8.3%), assault by poisoning (7%), transport accidents (0.8%), etc. During the 4-year study period, there were 122 cases in which the cause of death was related to CO in a study carried by Przepyszny et al. in Cleveland between 2000 and 2003.²⁷ Of these, 69% cases were classified as accidental, 25% as suicide, and 6% as homicide. The majority of accidental CO-related deaths were fire-related (77%), inhalation of automobile exhaust (13%), incomplete combustion of natural gas (7%), and other circumstances (3%). On the other hand, the majority of suicidal CO deaths were found to be resulted from the inhalation of automobile exhaust (90%). In 32 cases attributed to different reasons, HbCO levels were found to be 70–89% saturation, in 37 cases 50–69% saturation, in 23 cases 30–49% saturation, and in 28 cases less than 30% saturation. A 7-year retrospective study on medico-legal autopsies conducted by Department of Forensic Medicine and Toxicology, Medical School, University of Ioannina, Greece showed that 46 out of the 1582 autopsies (2.9%) were recorded as acute fatal poisonings.²⁸ Of 46 cases, 47.8% of the deaths were attributed to drugs of abuse overdose, 19.6% of the cases were attributed to pesticide ingestion, and 17.4% of cases were attributed to gas inhalation, exclusively CO. Total 139 cases out of 4402 autopsies were recorded as acute CO intoxication in Morocco during 1999–2007, an 8-year period.²⁹ Males were reported predominantly (55%) in accidental poisoning compared to females (45%). The highest frequency of CO deaths was found in February and March while we found it in January. In accordance with our study, the highest frequency of both not-fatal poisonings and actual fatalities due to CO intoxication was reported to be in the month January.³⁰ In the mentioned study, 346 deaths were due to unintentional CO related poisoning caused mainly by gas appliances in the homes. Regarding the gender differences, they found that non-fatal CO poisoning cases were higher in females than males, whereas actual fatalities were higher in males than females.

4.2. Clinical carbon monoxide poisoning data in Turkey

Table 3 summarizes and updates most of the clinical CO poisoning cases reported by different hospitals in Turkey up to now. Besides, Fig. 2 shows all the cities in which CO poisoning cases were reported by related emergency departments up to now. To describe the epidemiology of a pediatric population with accidental and suicidal poisonings admitted to the Emergency Department of Hacettepe University Children's Hospital during six-year period between 1995 and 2000, a retrospective study was planned by the

researchers.³¹ The mean age was 5.96 ± 4.87 years of 489 patients. The mode of the poisoning was quite different and 9.4% of all poisonings was due to CO poisoning. The inhalation poisoning due to CO was the second main route of poisoning in all the cases.

In another city hospital of Ankara, Gazi University Hospital, conducted a retrospective study on 323 adult emergency department patients diagnosed with CO poisoning between January 2002 and December 2003 (2 years). The majority of the patients were female (64%), all the poisonings were unintentional and the most common season was winter.³² The most common sources of CO were coal stoves (29%) and water heater appliances (24%). The symptoms of the patients were headache (55%), nausea (49%), dizziness (44%), syncope (28%), and seizures (4%) and the mean HbCO level was $26.3 \pm 11.5\%$. The death rate was not available in this paper.

Bursa is one of the most crowded cities of Turkey summing up 2.7 million populations in 2011. During the winter seasons, coal stoves are mostly used for heating and at least 900 people suffer from CO poisoning and some of them are hospitalized at the time of poisoning. A retrospective study was conducted to reveal prevalence, mortality rate and clinical predictors of the severity of CO poisoning in patients treated in emergency unit of Uludag University Hospital between 1996 and 2006 for an 11-year period.¹⁶ The number of poisonings in 10-year period was 305 and 10 of them died (3.3%) because of severe poisoning when were treated in intensive care unit or in emergency unit of the hospital. The other national studies and city of Bursa statistics as well as international studies report the mortality rate between 2.6% and 9.8%.^{33,34} The mean age of the poisoning cases was 36.8 ± 16.2 years ranging between 14 and 79 years. All poisonings were attributed to accidents except one suicide attempt. According to the source of CO in scene of accidents, they determined that the source was coal heater ($n = 262$, 85.9%), water gas heater ($n = 41$, 13.4%), and vehicle exhaust ($n = 2$, 0.7%). The main symptoms for mild poisoning cases when they come to the emergency room were headache, fatigue, nausea, and dizziness. Records for HbCO levels were determined in most of the cases and found to be $21.6 \pm 0.92\%$ of saturation ranging between 1 and 63%. According to seasonal distribution, they found that most of the cases occurred in winter ($n = 197$, 64.6%), followed by spring ($n = 75$, 24.6%), autumn ($n = 29$, 9.5%), and summer ($n = 4$, 1.3%). One-quarter of the patients were admitted to the intensive care unit of the hospital and 46 of them required mechanical ventilation. They stayed in this unit for 11.2 ± 15.8 days (mean \pm SD) ranging from 1 to 79 days. The other third-quarter of the patients were treated in the emergency unit of the hospital. The proportion of females (57%) was significantly higher than men. According to the Glasgow Coma score at admission, 59% of the patients were in mild CO poisoning, 13.4% was in moderate CO poisoning, and 27.2% of the patients were in severe CO poisoning.

Between 2000 and 2005 years 253,784 adult and 133,675 patients were admitted to one of the major hospitals in Ankara.³⁵ The records of 13,823 forensic cases (3.7%) were reviewed by the researchers. With 915 patients (6.6%), CO poisoning cases were the fourth most common cause of emergency; 88.8% of the CO poisoning cases were under 40 years old accumulating 20–29 years. Of all CO poisoning cases, 60% of them were female. The most common season was winter and very few cases were seen in spring and summer.

Uyanikoglu et al. conducted a study in Vakıf Gureba Training Hospital Emergency Unit, Istanbul, between January and December 2005 retrospectively to evaluate the demographics, etiologies and prognostic findings of intoxicated patients.³⁶ Of 794 patients, 83 (10.4%) were CO poisoning. Two patients were lost. The third most common cause of intoxication was CO in those patients.

Lastly, in a retrospective study conducted in a university hospital of Kayseri, a central Anatolian province, 682 poisoning cases were

investigated in emergency department.³⁷ Of the patients admitted to emergency room, 13.7% were CO poisoning which is the second most common poisoning type. The mortality rate was found to be 2%. In order to compare the mortality rates with other countries, we choose the study conducted by Malangu.³⁸ In 2005 and 2006, total 276 patients admitted to two hospitals and prediagnosed as acute poisoning in Jampala-Uganda. Of 276 patients, 55 patients (20%) were admitted to the hospitals due to CO poisoning and they were predominantly males. The overall fatality rate was 1.4%, of which 25% was due to CO intoxication.

5. Conclusion

CO poisoning has been accepted to be one of the leading significant health problems and leading cause of fatal poisonings in Turkey and many other countries. It is also responsible for a high incidence of severe morbidity and mortality. That is why Turkish society should be on high alert in attempt to prevent new cases of CO poisoning arising from coal heaters and appliances that use carbon fuels. Suicidal CO poisonings in Turkey are quite rare when compared to the other CO poisoning types like unintentional and occupational ones. It can be prevented partially through public education campaigns and prevention programs especially during winter months and regulations by authorities. Schools, governmental organizations, private initiatives and non-governmental organizations should educate the community about the dangers of charcoal, gaseous and liquid fuels for heating without the appropriate ventilation of living places. Residential CO sensors are very important for early detection of abnormal CO levels.³⁹ They should be generalized for public usage by the government as well as other private initiatives. The establishment of Poison Control Center/Centers is also an important factor to tackle with poisoning of CO.

Conflict of interest

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References

- McBay AJ. Toxicological findings in fatal poisonings. *Clin Chem* 1973;**19**:361–5.
- Abelsohn A, Sanborn MD, Jessiman BJ, Weir E. Identifying and managing adverse environmental health effects: 6. Carbon monoxide poisoning. *CMAJ* 2002;**166**:1685–90.
- Ruth-Sahd LA, Zulkosky K, Fetter ME. Carbon monoxide poisoning: case studies and review. *Dimens Crit Care Nurs* 2011;**30**:303–14.
- Fedakar R, Turkmen N. Fatal poisonings in the south Marmara region of Turkey, 1996–2003. *Eur J Gen Med* 2008;**5**:1–8.
- Ferrada-Noli M, Ormstad K, Åsberg M. Pathoanatomic findings and blood alcohol analysis at autopsy (BAC) in forensic diagnoses of undetermined suicide. A cross-cultural study. *Forensic Sci Int* 1996;**78**:157–63.
- Wintemute GJ, Teret SP, Kraus JF, Wright M. Alcohol and drowning: an analysis of contributing factors and a discussion of criteria for case selection. *Accid Ana Prev* 1990;**22**:291–6.
- Darke S, Zador D. Fatal heroin 'overdose': a review. *Addiction* 1996;**91**:1765–72.
- Li L, Smialek JE. Observations on drug abuse deaths in the State of Maryland. *J Forensic Sci* 1996;**41**:106–9.
- Birincioglu I, Karadeniz H, Teke HY. Fatal poisonings in Trabzon (Turkey). *J Forensic Sci* 2011;**56**:660–3.
- Buyuk Y, Kocak U. Fire-related fatalities in Istanbul, Turkey: analysis of 320 forensic autopsy cases. *J Forensic Leg Med* 2009;**16**:449–54.
- Azmak D. Asphyxial deaths: a retrospective study and review of the literature. *Am J Forensic Med Path* 2006;**27**:134–44.
- Cantürk N, Başbulut AZ, Cantürk M, Dağalp R. Ankara'da 2002–2006 yılları arasında Karbonmonoksit zehirlenmeleri otopsi olgularının değerlendirilmesi. *Adli Tıp Dergisi* 2008;**22**:25–30.
- Ertürk S, Hancı İH, Koçak A, Aktas EO. Deaths due to poisoning among forensic autopsies in Izmir between 1990–1994. *Ege Tıp Dergisi* 2001;**40**:117–9.
- Duman E, Akgur SA, Ozturk P, Sen F. Fatal poisoning in the Aegean region of Turkey. *Vet Hum Toxicol* 2003;**45**:106–8.
- Tekbas OF, Vaizoglu SA, Evci ED, Yuceer B, Guler C. Carbon monoxide levels in bathrooms using hot water boilers. *Indoor Built Environ* 2001;**10**:167–71.
- Akkose S, Turkmen N, Bulut M, Akgoz S, Iscimen R, Eren B. An analysis of carbon monoxide poisoning cases in Bursa, Turkey. *EMHJ* 2010;**16**:101–6.
- Metin S, Yıldız S, Çakmak T, Demirbaş S. 2010 Yılında Türkiye'de Karbonmonoksit Zehirlenmesinin Sıklığı. *TAF Prev Med Bull* 2011;**10**:587–92.
- Gören S, Tıraşçı Y, Üzünlü UDL. Banyo ölümlerinin retrospektif değerlendirilmesi. *Adli Tıp Dergisi* 2005;**19**:29–32.
- Türkmen N, Akgöz S. Deaths due to carbon monoxide poisonings autopsied in Bursa. *Adli Tıp Dergisi* 2005;**19**:20–5.
- Zhou L, Liu L, Chang L, Li L. Poisoning deaths in Central China (Hubei): a 10-year retrospective study of forensic autopsy cases. *J Forensic Sci* 2011;**56**(Suppl. 1):234–7.
- Liu Q, Zhou L, Zheng N, Zhuo L, Liu Y, Liu L. Poisoning deaths in China: type and prevalence detected at the Tongji Forensic Medical Center in Hubei. *Forensic Sci Int* 2009;**193**:88–94.
- Homer CD, Engelhart DA, Lavins ES, Jenkins AJ. Carbon monoxide-related deaths in a metropolitan county in the USA: an 11-year study. *Forensic Sci Int* 2005;**149**:159–65.
- Below E, Lignitz E. Cases of fatal poisoning in post-mortem examinations at the Institute of Forensic Medicine in Greifswald – analysis of five decades of post-mortems. *Forensic Sci Int* 2003;**133**:125–31.
- Naso C, Jenkins AJ, Younger 3rd D. A study of drug detection in a postmortem pediatric population. *J Forensic Sci* 2008;**53**:483–90.
- Zhu BL, Oritani S, Shimotouge K, Ishida K, Quan L, Fujita MQ, et al. Methamphetamine-related fatalities in forensic autopsy during 5 years in the southern half of Osaka city and surrounding areas. *Forensic Sci Int* 2000;**113**:443–7.
- Flanagan RJ, Rooney C, Griffiths C. Fatal poisoning in childhood, England & Wales 1968–2000. *Forensic Sci Int* 2005;**148**:121–9.
- Przepyszny LM, Jenkins AJ. The prevalence of drugs in carbon monoxide-related deaths: a retrospective study, 2000–2003. *Am J Forensic Med Pathol* 2007;**28**:242–8.
- Vougiouklakis T, Boumba VA, Mitselou A. Fatal poisoning in the region of Epirus, Greece, during the period 1998–2004. *J Clin Forensic Med* 2006;**13**:321–5.
- El Cadi MAKY, Idrissi L. Carbon monoxide poisoning in Morocco during 1999–2007. *J Forensic Leg Med* 2009;**16**:385–7.
- Nazari JDI, Stedmon A. Unintentional carbon monoxide poisoning in Northwest Iran: a 5-year study. *J Forensic Leg Med* 2010;**17**:388–91.
- Andiran N, Sarikayalar F. Pattern of acute poisonings in childhood in Ankara: what has changed in twenty years? *Turkish J Pediatr* 2004;**46**:147–52.
- Keles A, Demircan A, Kurtoglu G. Carbon monoxide poisoning: how many patients do we miss? *Eur J Emerg Med* 2008;**15**:154–7.
- Aksoy E, Polat O, İnanıcı MA. Retrospective analysis of 293 carbon monoxide poisoning cases. *Clin Dev* 1995;**8**:3545–9.
- Weaver LK. Carbon monoxide poisoning. *Crit Care Clin* 1999;**15**:297.
- Demircan A, Keleş A, Gürbüz N, Bildik F, Aygencel ŞG, Doğan NÖ, et al. Forensic emergency medicine – six-year experience of 13823 cases in a university emergency department. *Turk J Med Sci* 2008;**38**:567–75.
- Uyanikoglu A, Zeybek E, Cordan I, Avci S, Tupek T. Evaluation of intoxication cases. *Nobel Med* 2007;**3**:18–22.
- Kekce Z, Gunay N, Sozuer EM, Guven M, Sungur M. An analysis of 682 adult poisonings in central Anatolia of Turkey. *Vet Hum Toxicol* 2004;**46**:335–6.
- Malangu N. Acute poisoning at two hospitals in Kampala-Uganda. *J Forensic Leg Med* 2008;**15**:489–92.
- Sheikhazadi A, Anary SHS, Ghadyani MH. Nonfire carbon monoxide-related deaths: a survey in Tehran, Iran (2002–2006). *Am J Forensic Med Pathol* 2010;**31**:359–63.